

Review

The precipitous decline of the ortolan bunting *Emberiza hortulana*: time to build on scientific evidence to inform conservation management

MYLES H. M. MENZ and RAPHAËL ARLETTAZ

Abstract In recent decades there has been a marked decline in most ortolan bunting *Emberiza hortulana* populations in temperate Europe, with many regional populations now extinct or on the brink of extinction. In contrast, Mediterranean and, as far as we know, eastern European populations seem to have remained relatively stable. The causes of decline remain unclear but include: habitat loss and degradation, and related reduction in prey availability; climate change on the breeding grounds; altered population dynamics; illegal captures during migration; and environmental change in wintering areas. We review the current knowledge of the biology of the ortolan bunting and discuss the proposed causes of decline in relation to the different population trends in temperate and Mediterranean Europe. We suggest new avenues of research to identify the factors limiting ortolan bunting populations. The main evidence-based conservation measure that is likely to enhance habitat quality is the creation of patches of bare ground to produce sparsely vegetated foraging grounds in invertebrate-rich grassy habitats close to breeding areas.

Keywords Agricultural intensification, *Emberiza hortulana*, farmland birds, habitat degradation, migration, ortolan bunting, species decline, threatened species

Introduction

Migratory birds, in particular long-distance migrants, are vulnerable to environmental change in multiple regions (Sanderson et al., 2006; Both et al., 2010). The

ortolan bunting *Emberiza hortulana* is the only long-distance trans-Saharan migrant among old world buntings (Cramp & Perrins, 1994; Glutz von Blotzheim & Bauer, 1997). The species has undergone the second most pronounced decline of any bird species in temperate Western Europe in recent decades, with an estimated 82% population reduction between 1980 and 2008 (Klvanova et al., 2010), although the decline began earlier in some places (Conrads, 1977; Lang et al., 1990; Meier-Peithmann, 1992; Dale, 1997). Ortolan bunting populations have recently crashed across northern Europe and Scandinavia (van Noorden, 1991, 1999; Vepsäläinen et al., 2005; Ottvall et al., 2008) and the species has effectively become extinct as a breeding species within the last decade in Belgium, The Netherlands (van Noorden, 1991, 1999; Vieuxtemps & Jacob, 2002; van Dijk et al., 2005) and Switzerland (Revaz et al., 2005; Menz et al., 2009b), with mostly unpaired singing males remaining in these populations. The species has apparently remained stable in Eastern Europe (BirdLife International, 2004), and the only notable increase has been in Catalonia, in the Mediterranean (Pons, 2004; Brotons et al., 2008).

Although the life history of the ortolan bunting is generally well resolved we lack consolidated information about the species' key ecological requirements and most conservation action for the species is based on expert opinion rather than scientific evidence. Thus, there is uncertainty about the optimal conservation measures to implement. Given the challenges of integrating research programmes across regions and countries clear direction is required for appropriate conservation research for the ortolan bunting. In this review we: (1) synthesize existing knowledge of the biology of the ortolan bunting, (2) discuss the proposed causes of the species' decline, (3) propose priorities for future research to inform conservation action, and (4) provide preliminary evidence-based management recommendations from the information currently available (Pullin & Knight, 2001).

Literature searches were primarily on the ISI Web of Science, the Ornithological Worldwide Literature database (OWL, 2010), and reference lists from published articles. The review of threatening processes considered articles published after 1950 as this is believed to be the year in which many population declines began (Lang et al., 1990; Meier-Peithmann, 1992; Dale, 1997).

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Ecology of the ortolan bunting

Habitat requirements

In Mediterranean and sub-Mediterranean Europe the species breeds primarily in open shrubland and steppe-like habitat, particularly on south-facing slopes (Cramp & Perrins, 1994; Glutz von Blotzheim & Bauer, 1997; Fonderflick et al., 2005; Brotons et al., 2008). Here, the species favours areas with shrub and tree cover of c. 20–30% (Kölsch, 1959; Keusch, 1991; Menz et al., 2009a) and rarely occurs where tree cover exceeds 30–50% (Fonderflick et al., 2005; Fonderflick, 2006). In temperate Europe the species breeds primarily in agricultural habitats, particularly areas of small-scale cultivation, set-asides, short-rotation coppice and shrublands in historically burnt habitats, with these habitats often co-occurring (e.g. Berg & Pärt, 1994; Dale & Hagen, 1997; Berg, 2002; Dale & Olsen, 2002; Goławski & Dombrowski, 2002; Revaz et al., 2005). In farmland the species favours field margins with structural elements such as isolated trees, hedges and nearby forest margins (Meier-Peithmann, 1992; Grützmann et al., 2002), a characteristic shared by several farmland bunting species (Brambilla et al., 2008, 2009).

Within both natural and agricultural landscapes the ortolan bunting breeds primarily in relatively warm, dry areas, with well-drained soils and an annual rainfall below 600–700 mm (Cramp & Perrins, 1994; Grützmann et al., 2002), avoiding wet habitats (e.g. Nævra, 2002; Dale & Manceau, 2003; Hänel, 2004; Deutsch, 2007). Exceptions include populations occurring in areas with extremely well-drained soils and steep, sloping topography (Conrads, 1977). Ortolan buntings nest on the ground, typically producing only one brood per season, with exceptional replacement clutches and second broods (Garling, 1943; Conrads, 1969; Hänel, 2004).

Ortolan bunting populations typically consist of loose aggregations of breeding pairs (Vepsäläinen et al., 2007). Local colonization, extinction, and population fluctuations are often observed (Glitz, 1967; Dale & Steifetten, 2011), with areas seemingly isolated from other populations also colonized (van Noorden, 1991, 1999; Revaz et al., 2005). This could indicate the existence of a broadscale metapopulation structure, with areas being settled or abandoned as habitat suitability fluctuates following major disturbance events (Brotons et al., 2005). Short-term population increases have been observed in response to fire (Brotons et al., 2005, 2008), clearing of vegetation by a storm, forestry interventions, or cultivation (Conrads & Kipp, 1980; Nævra, 2002). Sparse vegetation and a large proportion of bare ground are the most noticeable common features of these habitats (Nævra, 2002). The species often becomes locally common after disturbance (Sposimo, 1988; Pons, 2004; Revaz et al., 2005) with, for example, populations peaking

3–4 years after fire (Pons & Clavero, 2010). This relationship is particularly strong in Mediterranean and, to a lesser extent, sub-Mediterranean biomes, where occurrence of fires is still commonplace, and it is also noticeable in temperate Europe where the species also nests on historic burns (e.g. Dale & Olsen, 2002; Revaz et al., 2005). This indicates that the ortolan bunting behaves like a pioneer species, typically colonizing the early stages of vegetation succession.

Diet

The ortolan bunting has a varied diet, including both plant (seeds) and animal matter (Cramp & Perrins, 1994; Glutz von Blotzheim & Bauer, 1997), although the diet of the chicks is restricted to a few dominant prey orders: Lepidoptera, particularly Tortricidae larvae, and Coleoptera in the north of its range (Conrads, 1968, 1969; Hänel, 2004), and Orthoptera, particularly Tettigoniidae, in the south (Kunz, 1950; Keusch & Mosimann, 1984). In Switzerland, Tettigoniidae made up nearly 70% of the total items provisioned to nestlings, a much higher percentage than in the sympatric rock bunting *Emberiza cia*, which has a more diverse diet (Keusch & Mosimann, 1984). In the north of the range caterpillars are fed to nestlings in the early stages of development, with diet switching towards larger prey in later developmental stages until post-fledging (Kunze, 1954; Knoblauch, 1968; Conrads, 1969; Hänel, 2004).

Foraging ecology

Ortolan buntings forage primarily in patches of bare ground within sparsely vegetated habitats (Stolt, 1974; Gnielka, 1987; Boitier, 2001; Menz et al., 2009b). However, prey such as caterpillars are also collected from fields (Conrads, 1969), or gleaned from tree crown foliage, particularly oaks *Quercus* spp. (Knoblauch, 1968; Conrads, 1969; Stolt, 1974; Gnielka, 1987), which harbour a relatively high density of caterpillars compared to other tree species (Naef-Daenzer, 2000). Adult males sometimes forage in the same oaks used as song posts (Hänel, 2004). Consequently, song post selection may function as a signal of territory quality, as oaks appear to be over-represented as song posts, compared to local availability of other tree species (M.H.M. Menz, pers. obs.).

In Switzerland most Tettigoniidae fed to nestlings are captured on the ground (Keusch & Mosimann, 1984) and in Germany Coleoptera are collected on paths or in cereal fields (Knoblauch, 1968). Tettigoniidae are most abundant in relatively dense steppe grass or bushes (Arlettaz et al., 1997). However, ortolan buntings do not necessarily forage in habitats with highest prey abundance but rather in those with a high proportion of bare ground (Menz et al., 2009b), as observed in other ground foraging birds (Wilson et al.,

2005; Schaub et al., 2010). Prey accessibility, therefore, rather than abundance, drives foraging habitat selection (Menz et al., 2009b; Schaub et al., 2010).

In temperate Europe foraging often takes place in cultivated fields, sometimes a distance away from breeding areas (Dale, 2000; Dale & Olsen, 2002). Cereal fields, particularly oats, are important for replenishing body fat prior to and upon return from migration, when birds feed on seeds and sprouting plants (Keusch, 1991; Grützmann et al., 2002). Oat is probably favoured because of the high energy content of the grain (Glutz von Blotzheim, 1989; Diaz, 1990).

Threats and reasons for decline

Habitat loss and degradation, and reduction in prey availability

Agricultural intensification has resulted in land-use changes such as homogenization of agricultural landscapes, loss of structural heterogeneity and an increased use of pesticides (Newton, 2004). A reduction of crop diversity and the transition in cultivation from summer to winter cereals may have contributed to the decline of the ortolan bunting, as such changes will limit the amount of bare ground in cultivated fields. Conversion of rye, and especially oat, to maize cultures has been reported to affect the species negatively (Maes et al., 1985; Ikemeyer & von Bülow, 1995; van Noorden, 1999; Grützmann et al., 2002; Deutsch, 2007; Berg, 2008), although this has not been quantified. Creation of monoculture agricultural habitats by destruction of structural habitat elements such as tree lines and hedges may be detrimental, as these provide song posts and foraging opportunities (Knoblauch, 1968; Vepsäläinen et al., 2005). Urbanization has often encroached into small-scale agricultural areas that had typically been preserved close to villages (van Noorden, 1999), increasing disturbance near to breeding areas (Steiner & Hüni-Luft, 1971).

One of the principal reasons for the observed decline of the ortolan bunting in temperate Europe is probably a reduction in prey availability/accessibility driven by habitat deterioration on the breeding grounds, primarily via changes in agricultural practices (Claessens, 1992; Kutzenberger, 1994; van Noorden, 1999; Grützmann et al., 2002; Revaz et al., 2005; Vepsäläinen et al., 2005; Deutsch, 2007). A reduction in patches of bare ground within foraging areas will result in decreased prey availability (Wilson et al., 2005; Schaub et al., 2010) in two ways. Firstly, agricultural intensification includes increased application of fertilizers, which closes the vegetation and suppresses patches of bare ground, and the use of pesticides eliminates invertebrate prey. Secondly, areas of bare ground also vanish following vegetation encroachment through natural succession after abandonment of traditional agricultural practices such as extensive grazing and burning of dry grass (Stolt, 1974; Dale,

1997; Nævera, 2002; Revaz et al., 2005; Wilson et al., 2005; Sirami et al., 2007; Menz et al., 2009b; de Groot et al., 2010). There is increasing evidence that reduction in structural heterogeneity and bare ground is threatening a number of ground-foraging farmland bird species (Wilson et al., 2005; Schaub et al., 2010).

Climate change on the breeding grounds

Climate change has been proposed as a possible cause of the decline of the ortolan bunting (Knoblauch, 1954; Helb, 1974; Maes et al., 1985; Grützmann et al., 2002; Vieuxtemps & Jacob, 2002). A low tolerance to cold temperatures (Wallgren, 1952, 1954) may increase the risk of physiological stress on breeding birds during inclement weather. Microclimate at the nest site is also likely to have consequences for the growth and survival of the nestlings (Conrads, 1977; Lang et al., 1990; Dale, 2000; Dale & Olsen, 2002; Grützmann et al., 2002; Vepsäläinen et al., 2005), as observed in other bird species (Ullrich, 1971). Poor weather during the breeding season, such as cold, rainy springs, also lowers reproductive success through nestling mortality from food limitation (Ruge et al., 1970; Fonderflick & Thévenot, 2002), something also observed in other species (Arlettaz et al., 2010).

The earlier growing season predicted under some climate change scenarios may lead to reduced foraging opportunities for ortolan buntings returning to their breeding grounds because of vegetation closure (Lang, 2007). The relatively short nestling phase (9–14 days; Cramp & Perrins, 1994; Glutz von Blotzheim & Bauer, 1997) means chicks require a large amount of invertebrate prey in a short period (Meier-Peithmann, 1992). Ortolan buntings may have evolved a reproductive phenology to coincide with peak prey availability, as seen in some other bird and mammal species (Blondel et al., 1991; Arlettaz & Fournier, 1993; van Noordwijk et al., 1995; Arlettaz et al., 1997, 2001). Chicks usually hatch in c. mid June, when Tettigoniidae are abundant and at a profitable size (Kunz, 1950; Arlettaz et al., 2001). Conrads (1968, 1977) noted breeding was synchronous with sprouting of oak leaves and the appearance of large numbers of defoliating caterpillars, although this was not quantified. Given the short breeding season and nestling phase, and their relatively late return from Africa (Claverie, 1955), altered climate regimes may see a mismatch between breeding period and prey availability (Both et al., 2010).

Altered population structure and dynamics

Studies from multiple regions have reported 29–60% of singing ortolan bunting males remain unpaired during the breeding season (Conrads, 1968; Dale, 2001; Fonderflick & Thévenot, 2002; Steifetten & Dale, 2006; Berg, 2008). However, even in declining and fluctuating populations

breeding success appears to remain stable (Maes, 1989; Steifetten & Dale, 2006). In small and isolated populations unpaired males may be all that remain prior to population extinction (Dale, 2001; Vieuxtemps & Jacob, 2002; Donald, 2007; Menz et al., 2009b). In Norway populations are limited by a drastic reduction in the number of breeding pairs because of females dispersing away from the population (Dale, 2001; Steifetten & Dale, 2006), resulting in the male-biased sex-ratio seen in declining populations (Dale et al., 2006). In relatively isolated populations there is little opportunity for recruitment of females from elsewhere (Steifetten & Dale, 2006). Declines and local population fluctuations are also driven by males undertaking relatively long-distance breeding dispersal in search of females (Dale et al., 2005; Dale & Christiansen, 2010; Dale & Steifetten, 2011). Loss of females from a population can only be mitigated by increasing the availability and suitability of habitat patches within breeding areas, which requires detailed knowledge of the species' habitat and foraging requirements (Steifetten & Dale, 2006).

Illegal captures during migration

The ability to constitute fat reserves rapidly before autumn migration seems to be an idiosyncrasy of the ortolan bunting, a characteristic known for centuries in gastronomic circles around Europe (Bastien, 1798; Kumerloeve, 1954; Claverie, 1955). The fact that the ortolan bunting is the only species of bunting in Western Europe that undertakes long-distance migration may indicate specific adaptations for storing fat reserves. Historically, large numbers of ortolan buntings were trapped during the autumn and, to a lesser extent, spring migration, mostly in southern Europe (Claessens, 1992). Small traps known as *matoles* are used that are baited exclusively with nearly ripe oat stalks (Claverie, 1955). It is likely that the species has become a delicacy because of its propensity to lay down fat relatively quickly when fed grain (oat and millet) *ad libitum* in captivity (Claverie, 1955; Claessens, 1992; Dale, 1997; Steifetten & Dale, 2006). After fire a wild form of oat occurs *en masse* in some Mediterranean habitats (R. Arlettaz, unpubl. data) and may have constituted an important food source prior to the expansion of agriculture.

In some areas of south-west France, despite the species now being protected, trapping and fattening continues unabated, with an estimated 50,000 birds illegally captured per year until at least the early 1990s (Claessens, 1992). No studies have been conducted on the consequences of this regionally intensive poaching on the demography of temperate European populations. Although it is unlikely that birds from all declining European populations of the ortolan bunting cross these areas during migration, in a wide-scale metapopulation system these losses may affect overall population dynamics and thus also have regional consequences for distant populations.

Environmental changes in wintering areas

Although the migration phenology is well documented for Europe (Stolt, 1977; Cramp & Perrins, 1994; Stolt & Fransson, 1995; Yosef & Tryjanowski, 2002; Bairlein et al., 2009), the wintering areas of the ortolan bunting are poorly known. Habitat changes in wintering areas because of climate variation and/or anthropogenic impacts on land (e.g. pesticides, Vepsäläinen et al., 2005; Zwarts et al., 2009) may also contribute to the observed population declines (Conrads, 1977; Kutzenberger, 1994; Busche, 2005; Vepsäläinen et al., 2005; Lang, 2007). However, the fact that some populations in the Mediterranean have been recently expanding (Brotons et al., 2008) seems to indicate that the problem may lie primarily with the quality of the breeding grounds in Europe, possibly compounded by environmental changes in African wintering areas. Identification of the wintering areas of this species is imperative for understanding factors that may be affecting the species outside the breeding season and whether birds from temperate and Mediterranean populations winter in different areas.

Discussion

Knowledge gaps and recommendations for future research

Further information on the diet of the ortolan bunting across its range, particularly quantification of nestling diet in relation to prey availability in the main foraging habitats, is required for a full understanding of the species' ecological requirements. In particular, quantification of the abundance and availability (the latter being abundance modified by accessibility) of major invertebrate groups in relation to the stages of vegetation succession following events such as fire may provide information on why the species colonizes these disturbed habitats during specific time windows (Pons & Claverie, 2010). Understanding the relationships between timing of breeding and prey phenology/availability would also elucidate the potential effects of weather and climate variation on reproductive output. Shifts in insect phenology could potentially lead to a mismatch between breeding season and prey availability, a phenomenon that may particularly affect long-distance migrants (Both et al., 2010).

More data are required on survival and movement patterns in areas where populations are stable (Pons, 2004). As most detailed studies on population structure and dynamics have been conducted in northern Europe (particularly Norway: Dale, 2001; Steifetten & Dale, 2006; Dale & Steifetten, 2011), a comparison between eastern European, Mediterranean and temperate populations would facilitate an understanding of the demographic

factors limiting populations, such as the propensity for females to disperse away from certain areas. Investigation into the extent of continued poaching would elucidate the potential effects this may have on the demography of temperate European populations as a whole.

Climate variation has already affected the ecology and distribution of some bird species (Arlettaz et al., 2010; Both et al., 2010). It is uncertain what effect predicted climate change scenarios would have on the ortolan bunting, especially given the paucity of data on future precipitation regimes (Easterling et al., 2000) and the impact of weather on the species' reproductive success. Studies at the edges of the species' range could provide insights into possible colonization of higher latitudes and altitudes. In Mediterranean Europe temperature increases may lead to abandonment of the warmest areas. Such studies are needed to disentangle the future effects of climate modification and ecosystem changes. Identification of the species' African wintering grounds by use of new light-weight tracking techniques such as geolocators (Bächler et al., 2010) would facilitate the assessment of any potential environmental issues that may be contributing to the decline of the species outside its breeding areas and elucidate the connectivity of European breeding populations.

Conservation recommendations

Until we know more about the specific factors limiting ortolan bunting populations, we recommend application of evidence-based conservation measures (Pullin & Knight, 2001) to counteract vegetation encroachment and increase the proportion of patches of bare ground within vegetated patches close to ortolan bunting breeding areas. This could be achieved through extensive grazing, controlled fire (Wilson et al., 2005; Schaub et al., 2010) and forestry interventions such as short-rotation coppicing (Berg, 2002). However, attention should be paid to protecting sufficient dense grass sward to support prey populations. Patches of bare ground in cultivated fields close to breeding areas may also be produced by spring sowing, decreasing seed sowing density or increasing the distance between rows in sown fields. Although prescribed fire may be a cost-effective management option that is already used in several countries to counteract vegetation encroachment (Montané et al., 2009), further research is required to determine the potential detrimental effects of prescribed burning on other aspects of biodiversity. In southern Switzerland extensive grazing, forestry measures (coppicing), sowing of oat fields and controlled fire have recently been applied simultaneously to halt the decline of a rare butterfly species and the ortolan bunting (E. Revaz & R. Arlettaz, unpubl. data). Thus in certain habitats conservation measures targeting the ortolan bunting may have broader benefits for biodiversity.

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